Microgrid R&D Program at the U.S. DOE

U.S. DEPARTMENT OF ENERGY

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

Program Manager: Dan Ton
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Advanced Grid R&D within OE

Grid Communications and Controls	Resilient Distribution Systems (RDS)	Advanced Distribution Management Systems; Microgrid R&D; Transactive Energy; Low Cost Sensors
	Transmission Reliability (TR)	Transmission Reliability; Advanced Grid Modeling
Grid Systems and Components	Transformer Resilience and Advanced Components (TRAC)	Advanced Components; GMD/EMP
	Energy Storage Systems (ESS)	Energy Storage

Defining Microgrids

A **microgrid** is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to enable it to operate in grid-connected or island-mode.

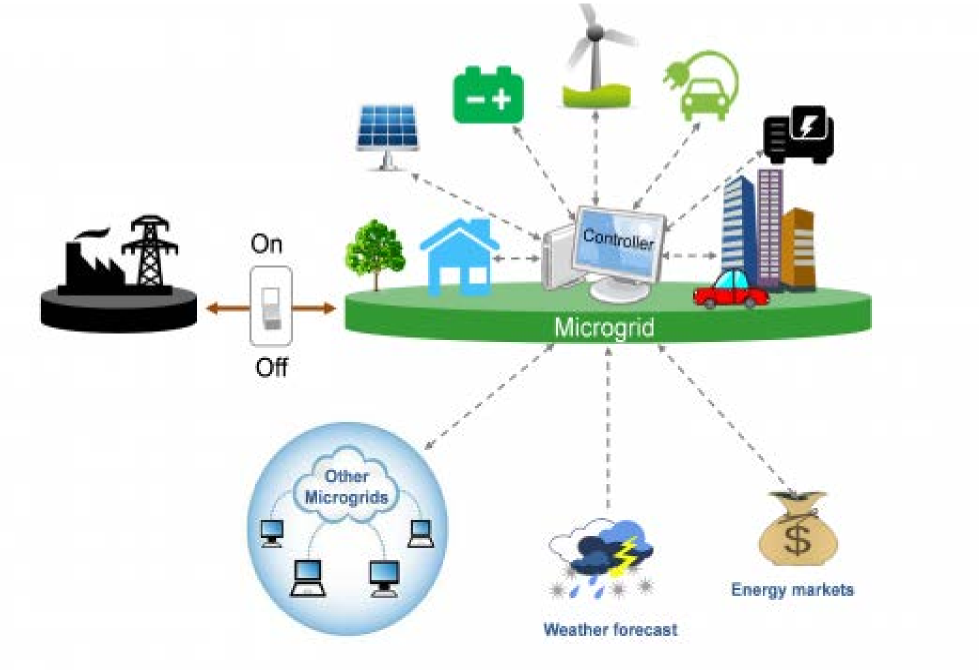


Image from Berkeley Lab

The Need for Microgrids

The current grid needs more redundancy to protect critical infrastructure and open new value streams.

Critical infrastructure is vulnerable to major disruptions.

Grid infrastructure should be neutral to generation sources while maintaining transmission reliability.

Intentional physical attacks could cause major damage.

Customers are seeking new opportunities to provide grid services to operators and tenants.

General Features of a Microgrid

- **Point of Common Coupling**
  A single interconnection point to the larger main grid
- **Energy Storage System**
  Both short-term and long-term capacity to “ride through” load transients and shift load peaks
- **DERs**
  Generation sources, both fossil and renewables
- **Primary Controls**
  Systems located locally at the DER to respond immediately to changes in microgrid frequency and voltage
- **Secondary Control**
  Supervisory level system that optimizes microgrid performance based on its operating objectives
- **System Protection**
  Specific protection systems to support island operation

Operational Modes of a Microgrid

Grid Connected

- Main grid provides primary control for frequency.
- Microgrid primary control is available to control voltage
- Microgrid secondary control used for optimization of microgrid DERs

Island Operation

- Microgrid provides primary control for both frequency and voltage since the main grid is not connected
- Microgrid secondary control used for optimization of microgrid DERs

Microgrids for Enhanced Resilience, Reliability, Economics, and Efficiency

Microgrids can serve crucial recovery centers during major weather or man-made disruptions that mitigate damage from storms and minimize impact from bad actors targeting the grid. Going forward, microgrids will seamlessly communicate with each other and/or the macrogrid to provide valuable services to grid operators to improve the cost-benefit of microgrid installations and provide low-cost solutions for grid management and damage mitigation.

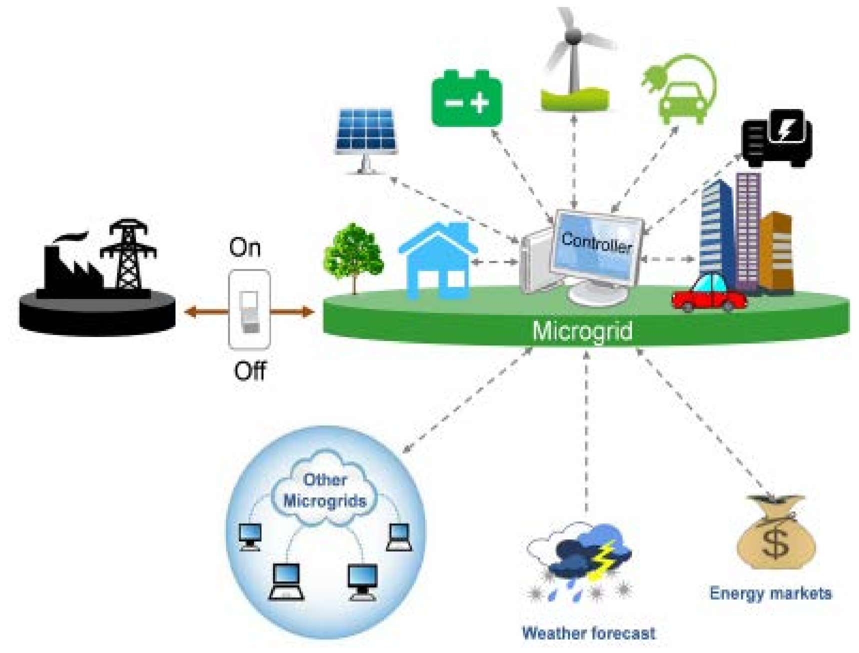


Image from Berkeley Lab

Microgrid Program Areas

Remote, Off-grid Microgrids

Grid-connected Microgrids

Networked Microgrids

Resiliency Tools

Standards and Testing

Remote, Off-grid Microgrids

Meet community-specific goals. In Alaska, the goal is to achieve a reduction in total imported fuel usage by 50%, while lowering system life-cycle cost and improving reliability and resiliency.

Projects for Presentation	
Performing Entity	**Project Title**
LBNL	ROMDST: Remote Off-grid Microgrids Design Support Tool
GMLC	Resilient Alaskan Distribution System Improvements Using Automation, Network Analysis, Control, and Energy Storage (RADIANCE)
SNL	Grid-bridging Inverter Application at St. Mary's/ Mountain Village Microgrid Systems
GMLC	Alaska Microgrid Partnership

ROMDST:
Remote Off-grid Microgrids Design Support Tool

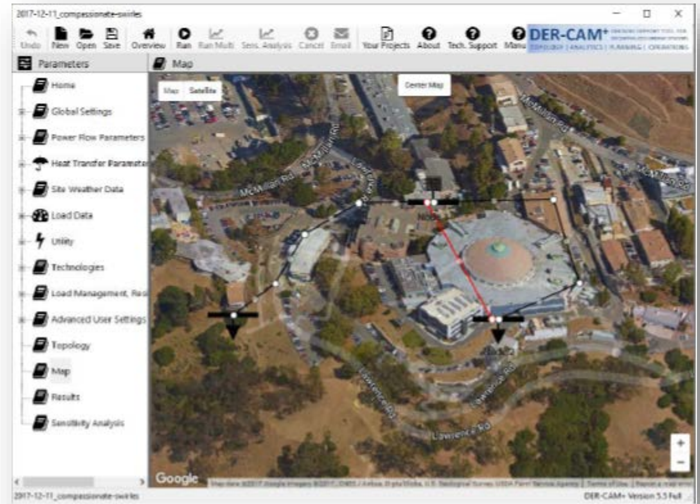
Leverage DER-CAM to deliver an optimization-based design support tool for remote, resilient, and reliable microgrids.

Phase I

- Duration: Oct 2015 – Aug 2016
- Focus on formulation and implementation
- Introduced new features, including multi-node, power flow, contingencies

Phase II

- Further development, validation testing, and transition to end-users, all completed in May 2018
- Published user manual; held training classes



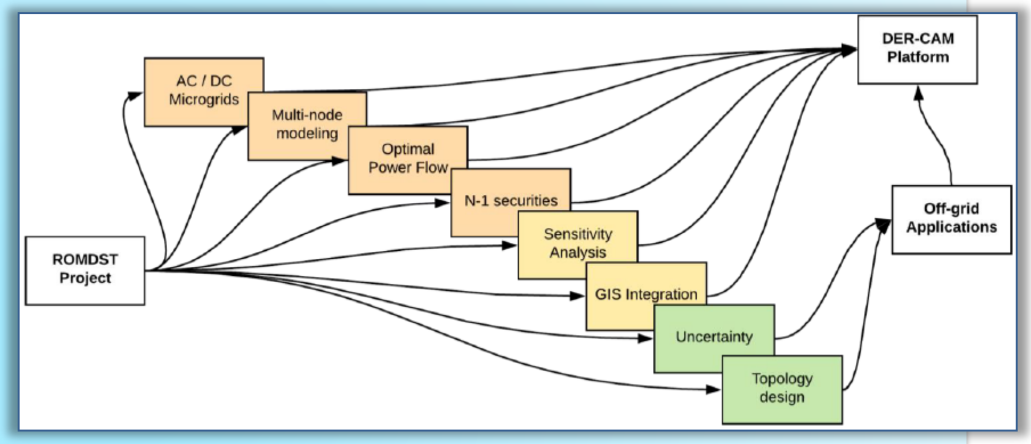
Active Partners

- LBNL, LANL, ANL, BNL
- Alaska Center for Energy and Power, General Electric, Burns Engineering

ROMDST:
Significance & Impact

Industry Needs/Challenges Addressed

- Multi-node modeling (community microgrids)
- Optimal DER placement
- AC & DC microgrids
- Security constraints (lines and generators)
- Topology design
- Uncertainty
- GIS integration



Expected Impact

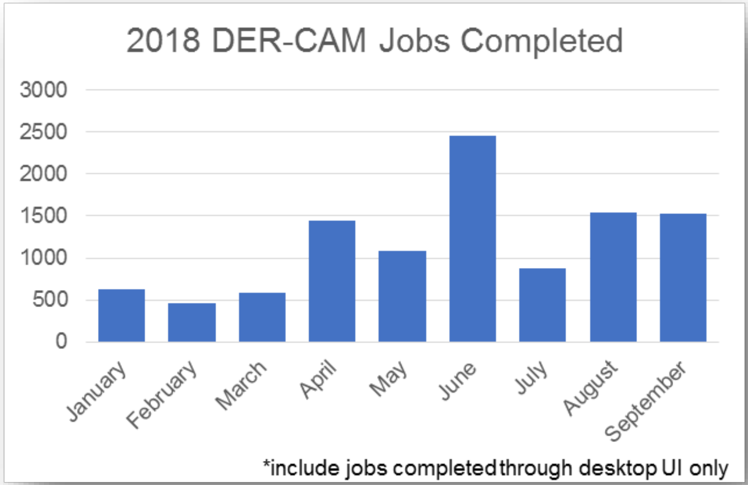
- Optimum off-grid microgrid designs, replacing existing back-of-the-envelope and non-optimal calculations
- Reduction in capital costs and risk of microgrid deployment
- Removing barriers to microgrid assessments by lowering microgrid soft costs, as the tool is freely usable
- Reliable and resilient microgrid designs that reduce the cost of critical load shedding due to component outages

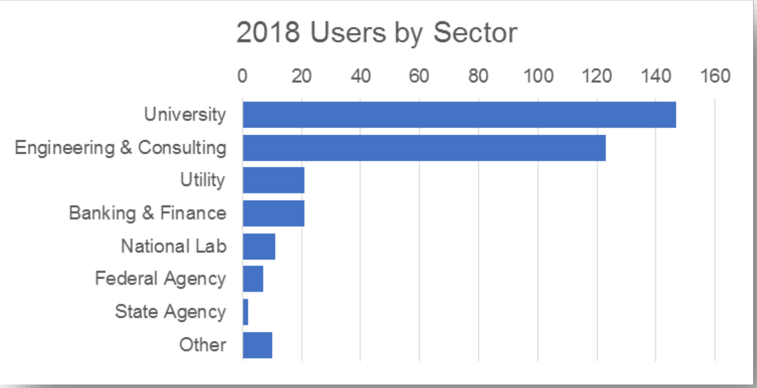
DER-CAM: State of the Microgrid Design Tool

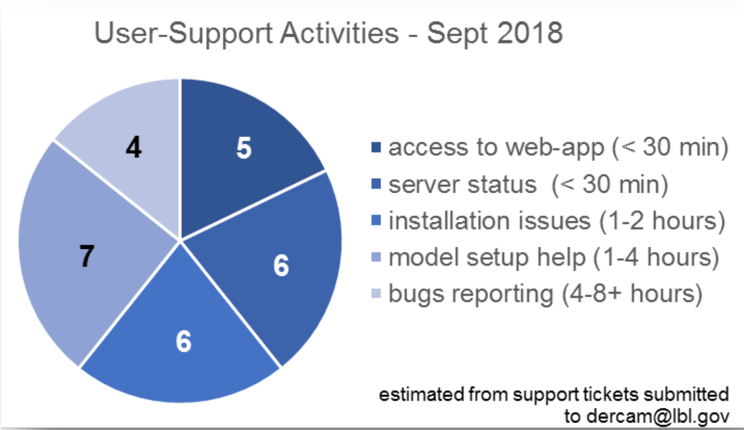
In FY18, DER-CAM was made easier to use by:

- ✓ Releasing the stand-alone desktop interface
- ✓ Releasing incremental improved versions
- ✓ Automating user registration
- ✓ Standardizing user-support ticket submissions via dercam@lbl.gov

- – Total user-base: > 1,800 users across versions
- – > 37,000 runs executed via desktop application
- – User-base grew by 6% in past 30 days
- – User-support activity ~1 request per workday







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DER-CAM Usability

The tool has four versions for different expertise and complexity levels:

- Basic
- Intermediate
- Advanced
- Full

Manuals and tutorial videos available at https://building-microgrid.lbl.gov/tutorial-movies-and-manual-full-der-cam-web

RADIANCE – Resilient Alaskan Distribution System Improvements Using Automation, Network Analysis, Control, and Energy Storage

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Field validation of resilience-based design and operation leveraging resources from multiple networked microgrids.

Scope

- Resilience Metrics Framework for Design and Operation – Develop and demonstrate practical use of resilience metrics for coordinated operation, design to minimize outages and financial losses
- Multiple Networked Microgrids in Distribution System – Leverage rotational and virtual inertia of microgrids assets including hydro, diesel, energy storage, and micro PMU-based sensing to enhance resilience of the overall regional distribution network
- Cyber-security Architecture and Rapid Prototyping of Controls – Rapid prototyping of controllers as HIL and cyber-vulnerability testing in a real-time cyber-secure environment
- Field Validation of Resiliency Enhancement Methods – Field validation of increasing resiliency of overall distribution system by leveraging resources from multiple networked microgrids

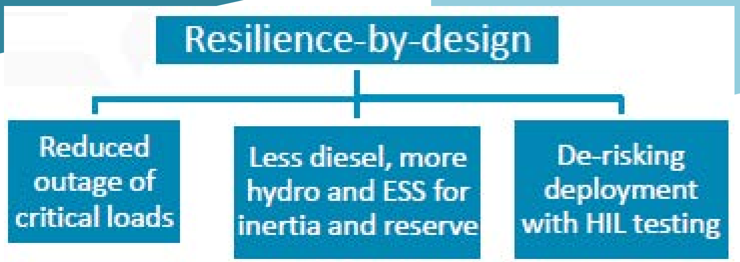
Significance and Impact

Industry need/challenge being addressed by the project

- Microgrids (loosely- and tightly-networked, standalone) as a resiliency resource.
- Adoption of early-stage grid technologies such as distribution PMUs.
- Integration of energy storage, fast-sensing and control requirements, and smart-grid technologies into existing grid control systems.
- Cyber-secure methods for ensuring **resiliency-by-design**, '*baked-in*' approach.
- De-risked, scalable deployment through cyber-secure unit and functional testing, progressive upscaling and iterative testing incorporating knowledge from partial field tests toward full-scale field validation.

Specific improvements/advancements targeted by the project with respect to reliability, resiliency, affordability, flexibility, security, and/or sustainability of electricity delivery

- Develop resiliency framework from multi-dimensional perspective including physical and cyber aspects.
- Deploy methodologies for tightly-, loosely-networked microgrid architectures as resiliency resource.



Approach - Resilience by Design

Resilience can be Enabled through Data-Driven Distribution Automation Technologies

- Spanning-tree & Critical-First Restoration Algorithm
- Deployment of advanced sensors and micro-PMUs
- Smart Switch and recloser placement to minimize outages
- Proactive Reconfiguration
- Big Data and Machine Learning

Simply dummy text of the printing and typesetting industry when an unknown printer took a galley of

- Outage management optimization

Working with Industry and Remote Communities

City of Cordova

Demonstration site; engineering support and regional expertise for field validation/deployment.

Cordova Electric Cooperative

Engineering support and regional expertise for field validation and full-scale deployment; approval on the networked microgrid design based on cyber-resilience framework.

Alaska Village Electric Cooperative

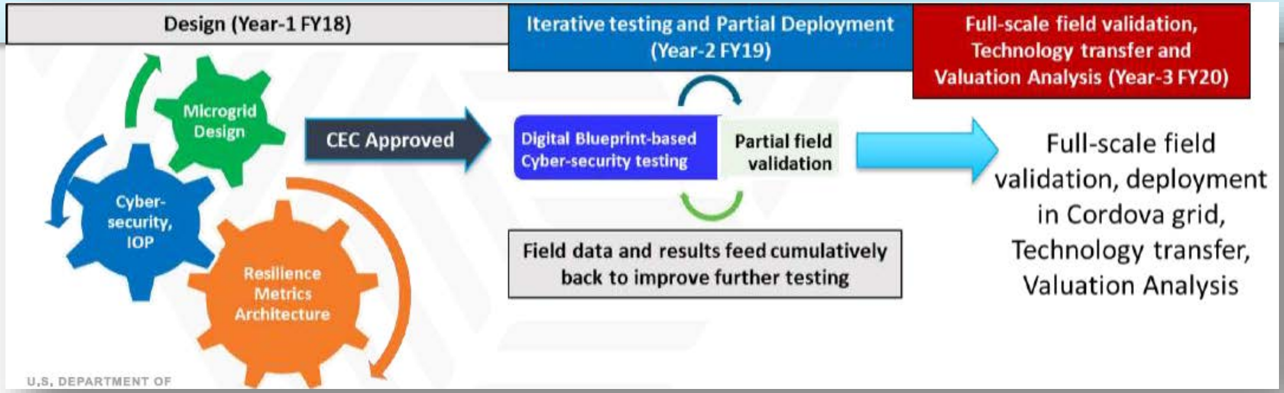
Local project coordination; information provider about remote sites and 58 dispersed villages in Alaska for feasibility of loosely-networked microgrids and operation with larger utility grids.

National Rural Electric Corporation of America

Regulatory structure for generalized knowledge assimilation and information dissemination from this project.

Siemens Corporation corporate Technology

Design and optimization of energy storage system with associated lower- and higher-level controls.

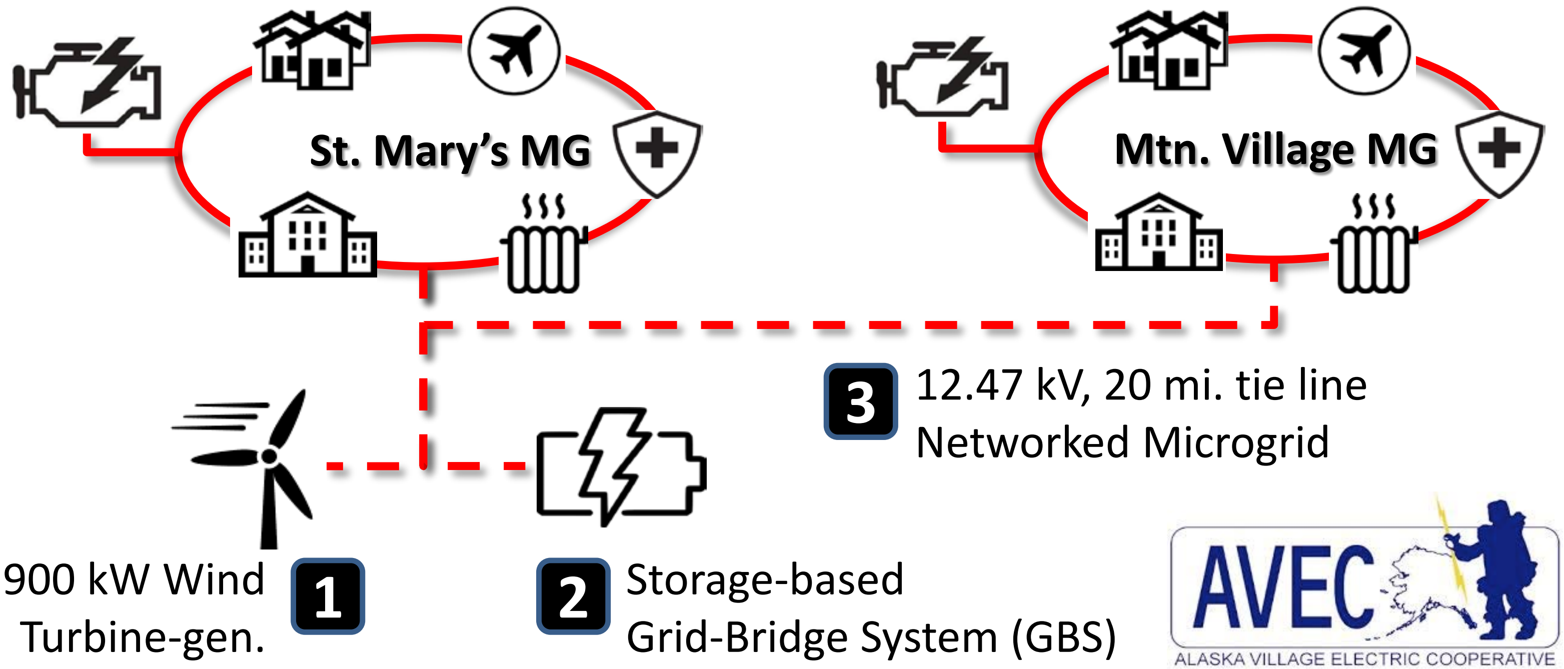


St. Mary’s and Mountain Village, AK

Energy Resilience Challenge:

- Both villages are rural microgrids supplied by diesel gensets
- Diesel fuel shipped up Yukon River, impassable August-April
- Life threatening issues if diesel runs out during winter
- High energy cost, >25% of average household income

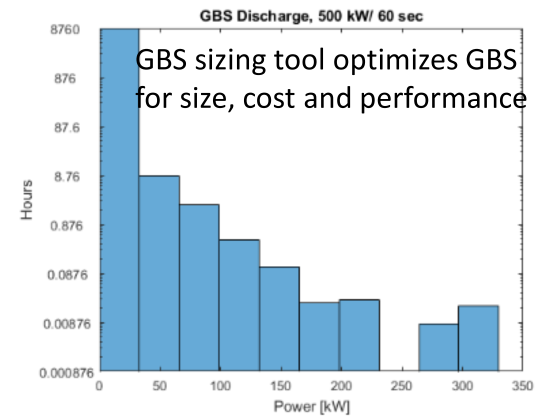
St. Mary's and Mountain Village, AK

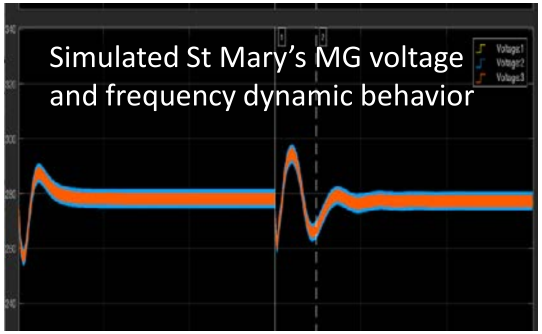


- Three-stage plan to lower costs and increase reliability and resilience
  1. Wind turbine-generator to reduce fuel use (DOE/IA)
  2. Storage-based grid bridge system (GBS) for spinning reserve (DOE/OE + DOD/ONR)
  3. Network St. Mary's MG with Mountain Village MG via 12.47 kV tie-line
- Eventual goal to run in diesels-off mode

St. Mary's and Mountain Village, AK

- Sandia National Labs Alaska, Village Electric Coop (AVEC), and Alaska Center for Energy and Power (ACEP), partnering to study and demonstrate advanced renewable-based microgrids
- Planned outcomes:
  1. Open-source GBS optimal sizing tool
     - Incorporates LCOE and performance models for a wide variety of storage technologies
  2. Validated open-source models for RE-based networked MG, including grid-forming inverters
  3. Demonstration of replicable and sustainable energy resilience solution for AK & beyond
     - 6 potential AK locations identified
  4. Identification of technology, standards, and workforce gaps relevant to the deployment of islanded and grid-connected networked microgrids

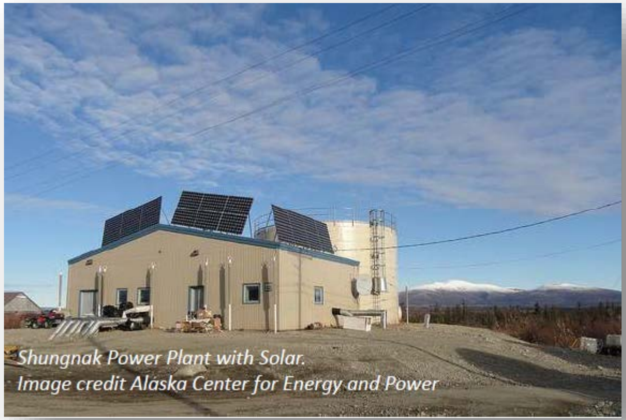




Alaska Microgrid Partnership

GRID MODERNIZATION INITIATIVE
U.S. Department of Energy

Reduce cost of energy for isolated communities by establishing information sharing resources for replacing imported fuels with local energy resources, energy efficiency, and optimized energy usage.



Shungnak Power Plant with Solar.
Image credit Alaska Center for Energy and Power

Outcomes

- Transitioned processes and methods for sharing and archiving lessons learned and design information to the Alaskan Energy Authority and the University of Alaska.
- Built Alaska Energy Data Gateway (website/repository) to allow stakeholders to collect and store information needed to implement innovative power systems.
- Led technical and economic analyses for the communities of Chefornak and Shungnak as examples of the pathway for assessing system feasibility.
- Developed numerous support documents and technical assessments to help communities implement their own development pathway.

Labs

LBNL, NREL, PNNL, SNL

Partners

Renewable Energy Alaska Project, Alaska Center for Energy and Power, Intelligent Energy Systems, Institute for Social & Economic Research

Where We Are – Where We Are Going

PAST	PRESENT	FUTURE
Campuses and Military Bases	Commercial Applications	Networked Microgrids
Single Owners	Grid-connected and Off-grid Applications	Multiple Value Streams
Microgrid Design Tools	Local, State, Multi-state and Regional Partnerships	New Ownership Models